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ABSTRACT

Vaccination Policy and Trust

We study the relationship between trust and vaccination. We show theoretically that vaccination rates are higher in countries with more transparent and accountable governments. The mechanism that generates this result is the lower probability of a transparent and accountable government to promote an unsafe vaccine. Empirical evidence supports this result. We find that countries perceived as less corrupt and more liberal experience higher vaccination rates. Furthermore, they are less likely to adopt a mandatory vaccination policy. One unit of the Corruption Perception Index (scaled from 0 to 10) is associated with a vaccination rate that is higher by one percentage point (pp) but with a likelihood of compulsory vaccination that is lower by 10 pp. In addition, Google Trends data show that public interest in corruption is correlated with interest in vaccination. The insight from our analysis is that corruption affects not only the supply but also the demand for public services.

JEL Classification: I18
Keywords: vaccination, corruption, COVID-19

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1 Introduction

Vaccination hesitancy (Jana and Osborn, 2013) was on the World Health Organization's list of 10 most critical public health threats in 2019.[1] Unsurprisingly, concerns regarding future COVID-19 vaccination hesitancy emerged as early as the beginning of vaccine development. For instance, long before mass vaccinations started, Harrison and Wu (2020) and Verger and Dubé (2020) discuss how hesitancy may jeopardize the fight against the pandemic. Lin et al. (2021) report a review of 126 surveys on COVID-19 vaccination intentions, including 23 academic studies and 103 opinion polls published before November 2020. The authors find that COVID-19 vaccine hesitancy is increasing worldwide.[2] In a large French survey with randomisation of vaccine characteristics, Schwarzinger et al. (2021) show that the level of COVID-19 vaccine hesitancy is heterogeneous over ages and across different vaccines.

Although this paper's research question is germane to all vaccines, the recent COVID-19 pandemic provides an important motivating case study. A salient ongoing event related to the topic is the case of the Russian COVID-19 vaccine Sputnik V. The rapid development of the vaccine, which was approved in Russia already in August 2020, is seen by the Russian government as an impressive national achievement. Vaccination is free, available in public places, and advertised. Yet only 1.2% of Russians received full vaccination by the end of February 2021. By the end of June, on the eve of the third wave of the pandemic in Russia, the share of fully vaccinated was only 8.2%, while an additional 3.2% received some vaccination. During June, the government imposed sanctions against non-vaccinated individuals, threatening their dismissal from public service jobs. The sanctions (or fear of

[1] Vaccination is only one of the means of protection against disease transmission. For a theoretical model of protection, see Goyal and Vigier (2015). For a general framework of life saving policy, see Zeckhauser and Shepard (1976).

[2] Sallam (2021) is a smaller review of COVID-19 vaccination hesitancy studies.

them) had some effect but not an overwhelming one. By the end of July, the share of fully vaccinated increased to 17%, while an additional 7.8% received some vaccination.

The most important lesson from the Russian case is that the low public response to the vaccine's promotion is not a result of attitudes to vaccination in general or to evidence on Sputnik V's performance. According to a series of polls by the Levada Center,[3] only 1% of Russians are "against any vaccination." Meanwhile, around 60% are not ready to be vaccinated with Sputnik V. This figure even increased over time (from 55% in August 2020 to 62% in April 2021), as the government's propaganda campaign intensified.[4] It is also worth noting that no hard evidence with regard to the quality of Sputnik V overturned the positive test results, published in two influential articles in the prestigious Lancet journal (Logunov et al., 2020, Jones and Roy, 2021). Therefore, the lack of trust in Sputnik V is not a result of lack of trust "in science" but a result of lack of trust in a government that promotes the vaccine.

Generally, individuals who resist vaccination are not necessarily indifferent to the disease. One of the reasons for vaccine hesitancy is free riding. As more people are already vaccinated, the risk of being infected is lower. Thus, a person may not prefer paying the cost of vaccination (Brito et al., 1991, Francis, 1997, Laguzet and Turinici, 2015). Further, there are ideological and religious reasons to resist vaccination, and fears about possible negative side effects. Providers may supply vaccines of low quality. In some cases, resistance to vaccination is associated with conspiracy theories, which accuse pharmaceutical companies of pressuring physicians and governments (Johnson, 2013). Another reason for hesitancy is a well-known controversy related to vaccination that goes back to Wakefield et al. (1998),

[3] The Levada Center is a well-recognized and independent sociological research organization. Since 2013, it has been persecuted as a "foreign agent" for publishing polls showing public criticism of the Kremlin.

[4] Source: https://www.levada.ru/en/2021/05/19/coronavirus-and-vaccination/.

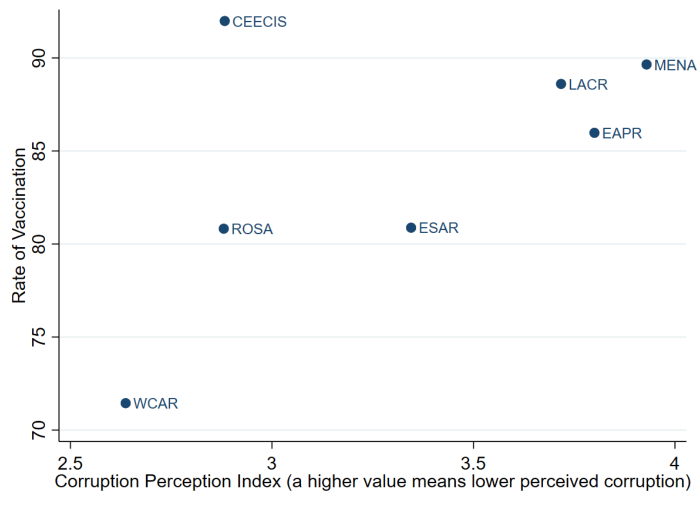
who claimed that the measles, mumps, and rubella (MMR) vaccine may cause autism. This finding was not supported by further research. Moreover, Wakefield's analysis was later found to be fraudulent. However, the public debate about the linkage between autism and vaccination still persists into the present (Chatterjee, 2013).

The propensity of such sentiments is related to the general level of citizens' trust toward the government. For instance, at the beginning of the COVID-19 pandemic, Bargain and Aminjonov (2020) document a positive interaction between trust and policy in the reduction of mobility. Similarly, governments can adopt different vaccination policies. It can recommend or not recommend vaccination. It can also make vaccination compulsory for high-risk groups or for everyone. However, the effectiveness of different polices is debatable. For instance, the European Union (EU)-funded ASSET project finds no clear relationship between mandatory vaccination and the rates of childhood immunisation in the European Union/European Economic Area (EU/EEA) countries.[5] Meanwhile, Abrevaya and Mulligan (2011) find favourable evidence on the effectiveness of mandatory vaccination policies in the USA. Furthermore, Lawler (2017) finds evidence supporting the effectiveness of both recommended and mandatory vaccination policies (see Ward, 2014 as well). In theory, the social planner may choose not to enforce vaccination on the whole population (Manski, 2017).

Here, we study the outcome of the government's vaccination policy considering trust in the government. We propose a theoretical model where a government is interested in promoting vaccination. It can also seek to save costs, and therefore, choose low quality vaccination. Low quality vaccination may also be protective, and then citizens will choose to vaccinate even if believe that the quality is low. However, low quality vaccination may be harmful. In this case, citizens will not vaccinate if they believe that the quality is low.

[5] http://www.asset-scienceinsociety.eu/reports/page1.html

Figure 1: Corruption and vaccination



Note: The figure shows average cross-country vaccination rates vs Corruption Perception Index. Countries are grouped by region. Vaccination data is from UNICEF.

Harmful vaccination also has costs for the government, political or otherwise. The lower the transparency and accountability of a government, the lower is the expected costs for the government for choosing low quality vaccination. Thus, the government has more incentive to choose low quality, and, therefore, the share of vaccinated citizens becomes lower. As distrust in the government's goals increases, less citizens choose to vaccinate voluntarily. This may encourage the government to adopt a compulsory vaccination policy.

In the empirical section, we provide evidence in line with our theoretical predictions. The lower is the level of perceived corruption (measured by the Corruption Perceptions Index), the higher is the share of the vaccinated population. This relationship is simply illustrated in Figure 1, where each point represents a group of countries. In the regression analysis, we control for fixed effect, level of civil and political freedom, and human development. Yet the coefficient of perceived corruption on vaccination rate remains robustly around one percentage point for each point of CPI (scaled from 0 to 10). Moreover, across European Union countries, less corrupt countries are less likely to adopt a mandatory vaccination policy. A possible explanation is that citizens trust the recommendations of less corrupt governments, and, therefore, the government does not need to force citizens to vaccinate. Moreover, the level of civil rights in a country is negatively correlated with a mandatory vaccination policy. Finally, in the Google Trends data, we use factor analysis to show the existence of a common factor that drives public interest in corruption, vaccination, and autism; however, this factor is not related to placebo search terms.

The closest research to our paper is Li et al. (2018), who estimate the relationship between corruption and (among other outcomes) vaccination rate in a panel of countries. Our paper is an extension in several domains. First, we discuss a theoretical model that links government accountability to vaccination rate, and thus we frame our study in the context of demand for vaccination in the presence of corruption and not just a corruption-vaccination correlation. Second, from an empirical perspective, our sample of vaccines is larger, culminating in 14,000 observations in the pooled regression versus 2,000 in Li et al. (2018). Finally, we consider additional empirical aspects: propensity of mandatory vaccination and joint public interest in vaccination and corruption.

Our theoretical discussion focuses on vaccination hesitance, i.e., on demand for vaccination in the presence of corruption. By contrast, previous literature is limited almost entirely to the effect of corruption on delivery of public services (including vaccination), i.e., on the supply side. For instance, Barr et al. (2009) provide an experimental study of the effect of corruption on public goods delivery, Rajkumar and Swaroop (2008) investigate the causal effect of corruption on child mortality, and Lindelow and Serneels (2006) provide anecdotal evidence of low performance of a corrupt health sector. Goel and Nelson (2021) find that across the United States, corruption heritage is associated with a faster COVID-19 vaccination and suggest that corruption has a "greasing" effect that accelerates delivery of public services in critical situations. In contrast, in a cross-country correlation, corruption is associated with slower COVID-19 vaccination (Farzanegan and Hofmann, 2021). In the context of international economics, Dietrich (2011) claims that corrupt governments in developing countries may deliver more vaccination, because it is a relatively cheap signal of efficiency used to attract foreign aid. However, De la Croix and Delavallade (2009) argue that corrupt governments are likely to invest less in the health, because rent-seeking in health sector is relatively difficult. Moreover, Rajkumar and Swaroop (2008) and Sommer (2020) find that the effect of public spending on health is better in countries with good governance, while Kolesar and Audibert (2017) document in a field experiment that reduction of vaccine-preventable mortality is enhanced by other investments, such as education. In addition, Kim et al. (2011) find that trust is positively related to self-reported health. Finally, Goel et al. (2021) consider the reverse causal link from vaccination to corruption and argue that the COVID-19 vaccine provides opportunities for corruption.

2 Model

Complete information

Assume a government that decides on a policy of vaccination against some disease. In a continuum of citizens of unit mass, each citizen i has a private cost c_i to be vaccinated. We assume that all c_i are independent and identically distributed from the interval $[0, 1]$, and are distributed according to a distribution function $F(c)$. We assume that $F(c)$ is strictly increasing. If a share of citizens $x \in [0, 1]$ is vaccinated, one component of the government's benefit is a non-decreasing $b(x)$. This term depends on the number of vaccinated citizens only and disregards the effectiveness of the vaccination. For instance, the government may be interested in increasing the revenues of vaccination providers.

A government G chooses to provide either standard (q) or low-quality vaccination ($\bar{q}$). The decision about quality is made for all vaccines. This quality is the government's private information. If the quality is standard, the vaccine is useful; if the quality is low, the vaccine is less useful or may even be harmful. The costs of the standard and low-quality vaccinations are dx and gx, respectively, where $0 < g < d$. The government has an additional utility from choosing a standard-quality vaccination, vx, $v > 0$. If use of the low-quality vaccination is revealed, G pays an ex-post cost of $0 < \gamma < 1$. However, this quality is revealed only with a probability $p = x^{\alpha}$, where $0 < \alpha < 1$. The utility function U_G of G is expressed as follows:

$$U_G = \begin{cases} b(x) + vx - dx & , G \text{ chooses } q \\ b(x) - gx - \gamma x^{\alpha} & , G \text{ chooses } \bar{q} \end{cases} \tag{1}$$

Trivially, if $v > d - g$, the benevolent G always chooses q. Hereafter, we assume $v < d - g$.

Assume that $\frac{\partial b(x)}{\partial x}$ is sufficiently high, such that U_G increases for all x.

Note that if $0 < \alpha' < \alpha$ and $0 < x < 1$, then $x^{\alpha} < x^{\alpha'}$. A higher α means that G has a lower probability of revealing lower quality of vaccination. Therefore, we refer to a higher α as a *less transparent* government. One interpretation of γ is how severe the price paid by G is if the low quality is revealed. We refer to γ as government *accountability*.

If a citizen does not vaccinate, her utility is $n(x)$. We assume $n(x)$ is non-decreasing and $n(0) \geq 0$. If citizen i with a cost c of vaccination is vaccinated, and the vaccination is of standard quality, i's utility is $h(x) - c$, where $h(x)$ is non-decreasing and $h(x) > n(x)$ for all $x \in [0, 1]$. If the quality is low, i's utility is $l(x) - c$, $l(x) < h(x)$ for all $x \in [0, 1]$. In summary, if i's cost of vaccination is c, utility $V(c)$ of i is expressed as follows:

$$V(c) = \begin{cases} n(x) & , i \text{ is not vaccinated} \\ h(x) - c & , i \text{ is vaccinated and } G \text{ chooses } q \\ l(x) - c & , i \text{ is vaccinated and } G \text{ chooses } \bar{q} \end{cases} \tag{2}$$

We assume that if citizens are indifferent between vaccinating or not, they vaccinate.

The following proposition states that the rate of vaccination increases with the level of government transparency.

Proposition 2.1 *Let $v < d - g$. Assume that $h(x) - n(x)$ decreases in x. Let $\tilde{x} \in [0, 1]$ be the share of citizens who vaccinate in equilibrium. Then, $\tilde{x}$ weakly decreases in α and weakly increases in γ.*

A proof appears in the Appendix. If even a low quality vaccine is sufficiently protective, i.e., $l(x)$ is sufficiently high, then a high share of citizens vaccinates. But if low quality is less useful relative to vaccination cost, or is even harmful, i.e., $l(x) < n(x)$, citizens vaccinate in equilibrium only with a high quality vaccine. There is some threshold, denoted by x', such that G provides high quality vaccines if and only if x does not exceed this threshold. This threshold decreases in α: if government is less transparent, it is less reluctant to provide low quality. Similarly, this threshold increases in γ: if government is more accountable, it is more reluctant to provide low quality.

If the share of vaccinated citizens is sufficiently high, the government prefers to provide low quality. On the one hand, for high x the probability that $\bar{q}$ is revealed is high. On the other hand, for high x the government saves more vaccination costs if it chooses $\bar{q}$. Since we assume concave p, for high share of vaccination the latter effect is stronger than the former.

We illustrate proposition 2.1 in Figure 2. We assume $b(x) = 5x$, $v = 1$, $d = 5$, $g = 2$, $n(x) = \sqrt{x}$ and $h(x) = 0.5 + \sqrt{x}$. We consider also $l(x) \equiv 0$ and $F(c) = c$.

We show in the figure the area where the government prefers to provide quality, and the area where citizens prefer high-quality vaccination to non-vaccination. The minimal out of these two areas is the share of vaccinated citizens, which decreases in α and increases in γ. This area is fulfilled in the figure.

The assumption that $h(x) - n(x)$ is decreasing is realistic. If more people are vaccinated, the risk of being infected decreases. Therefore, the marginal impact of vaccination diminishes.

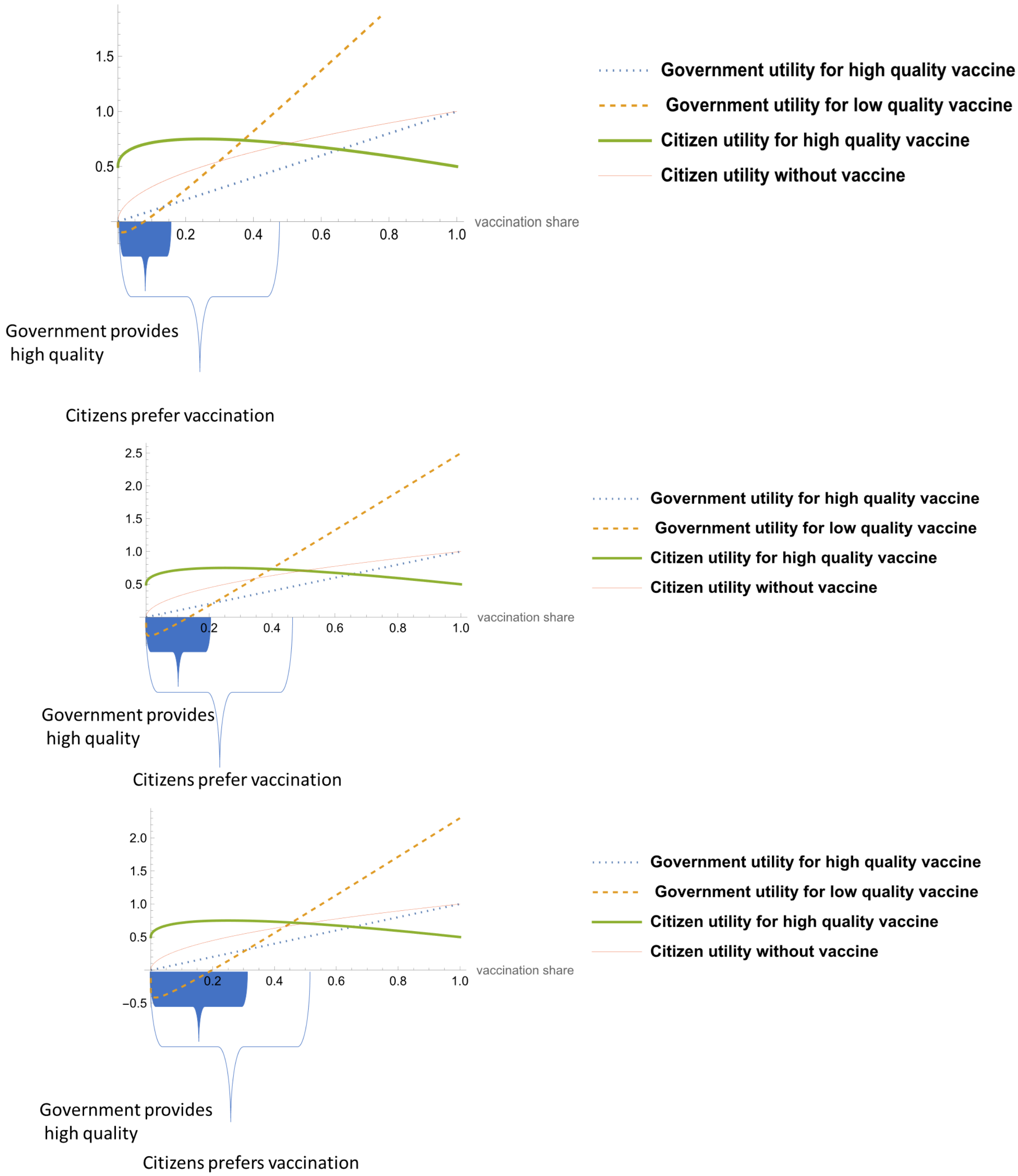
Censorship of rumors about vaccination

Another related issue is censorship of (true or false) information regarding vaccination. For example, in the UK, there were debates on legislation that imposes penalties on social media platforms for not removing false stories about vaccines.[6] Indeed, false rumors about vaccine side effects may reduce people's readiness to vaccinate. However, the presence of censorship itself may undermine trust in a government in general, and particularly in vaccine safety. The reason is that rumors grow in the censored part of the information set. While the peril of a disease and the benefits of vaccination are commonly advertised, the side effects of the vaccine may be targeted by censorship. Rumors fill this information vacuum and are free to exaggerate the side effects. As a result, rumors are directly focused on decreasing trust below its "true" value.

To handle this topic, we suggest the following interpretation of our model. Citizens are not sure how safe even high-quality vaccination is. Then, $h(x)$ is the perceived expected utility from vaccination. Rumors that vaccines are unsafe may lower $h(x)$ for each x. Therefore, the

[6] https://www.bbc.com/news/uk-politics-54947661

Figure 2: Vaccination share



Note: The figures are for $\alpha = 0.3$, $\gamma = 0.5$, $\alpha = 0.1$, $\gamma = 0.5$ and $\alpha = 0.1$, $\gamma = 0.7$, respectively.

share of vaccinated citizens decreases as such rumors spread. This may justify a censorship policy. Yet with censorship, it is easier to conceal low-quality vaccination (high α in our model). Then, by proposition 2.1, $\tilde{x}$ decreases.

Incomplete information

In this section we assume for simplicity that $l(x) < n(x)$ for all $x \in [0,1]$, namely, citizens do not vaccinate if vaccine quality is low. Suppose the government can be one of two following types. With probability ρ the government is *benevolent* and its utility is as in (1). One may interpret ρ as the level of trust in the government's goal. However, with probability $1-\rho$ it is *selfish*. The selfish government has no additional utility from choosing a standard-quality vaccination. For instance, it may be the case that it is only interested to enhance revenues of vaccination providers. Thus, its utility U_b is expressed as:

$$U_b = \begin{cases} b(x) - dx & , G \text{ chooses } q \\ b(x) - gx - \gamma x^{\alpha} & , G \text{ chooses } \bar{q}. \end{cases} \tag{3}$$

Recall that x is the share of vaccinated citizens.

If G is selfish with certainty, then, similar to the proof of proposition 2.1, it is easy to prove the following lemma.

Lemma 1 *Let $\rho = 0$. Assume that $h(x) - n(x)$ decreases in x. Let x^* be defined as in the proof of proposition 2.1. Then $\tilde{x}' = \min[x^*, (\frac{d-g}{\gamma})^{\frac{1}{\alpha-1}}]$, where $\tilde{x}'$ is the share of citizens who vaccinate in equilibrium.*

Next, consider a case where G's type is not known, $0 < \rho < 1$. Suppose that a citizen's utility of low-quality vaccination is constant, $l(x) \equiv l$, $l < 0$.

Proposition 2.2 *Assume $h(x) - n(x)$ decreases in x. The share of citizens who vaccinate in equilibrium weakly increases in ρ. For $0 < \rho < 1$ this share is not higher, and for some values of ρ is lower than in the case of $\rho = 1$.*

One of the conclusions from proposition 2.2 is in an incomplete information case where the share of vaccinated citizens may be lower compared to a case where $\rho = 1$. This may provide an incentive to a benevolent government to enforce vaccination by making it mandatory.

3 Empirical evidence

Our theoretical prediction is that the readiness to be vaccinated increases with government transparency and accountability and decreases as there is less confidence in the government's goal. The latter point may encourage a distrusted government to adopt a compulsory vaccination policy. We assume that accountability, transparency, and trust are highly correlated with perceived corruption of the government. Thus, we use perceived corruption as an explanatory variable.

Rate of vaccination and corruption

In equilibrium, characterised by Proposition 2.1, the share of vaccinated citizens increases as the government is perceived to be less corrupt. We test this prediction empirically.

Data and model

First, we consider the relationship between vaccination rates and corruption. We use UNICEF's estimates of vaccination rates by country for years 1998–2011 and the Corruption Perception Index (CPI), compiled by Transparency International, for the same years. The range of years is bounded by the first CPI report and the change in the methodology of CPI calculation, which took place in 2012.

Thus, we have three dimensions of variation in the vaccination rates, namely, across countries, years, and vaccines. This allows us to estimate a model where we control for country and year fixed effects (or for country-specific linear trends in a more conservative model). This model is expressed as follows:

$$Y_{itv} = \beta CPI_{it} + \gamma_i + \delta_t + \mu_v + \varepsilon_{it}, \tag{4}$$

where Y_{itv} is the vaccination rate (in the target population) of vaccine v in country i in year t, and γ_i, δ_t, and μ_v are country, year, and vaccine fixed effects, respectively.

Table 1 reports the summary statistics of vaccination rates and CPI by region.

Results

Table 2 shows the results of estimating Equation (4). We cluster the standard errors at the country level. Column 1 shows the results for a pooled sample of all vaccines with vaccine fixed effects. Columns 2–9 show the results of separate regressions for each vaccine with at least 1,000 observations. It includes: BCG - Baccille Calmette Guérin vaccine; DTP1 - First dose of diphtheria toxoid, tetanus toxoid, and pertussis vaccine; DTP3 - Third dose of diphtheria toxoid, tetanus toxoid, and pertussis vaccine; HepB3 - Third dose of hepatitis B vaccine; Hib3 - Third dose of Haemophilus influenzae type B vaccine; MCV1 - Measles-containing vaccine; Pol3 - Third dose of polio vaccine; and RCV1 - Rubella-containing vaccine 1st dose.

Panel A presents results of the estimation with country and year fixed effects, while Panel B presents the results for the estimation with country-specific linear trends besides the fixed

Table 1: Summary statistics (vaccination rates and CPI), 1998–2011

Region	Vaccination rate							CPI
	BCG	DTP1	DTP3	HepB3	Hib3	MCV1	RCV1	
E. Europe (non-OECD)	95.6 (4.8)	96.0 (5.5)	93.5 (7.4)	82.6 (22.9)	82.5 (23.7)	92.6 (7.6)	93.3 (6.5)	3.79 (1.99)
Central Asia	95.8 (7.1)	97.1 (3.1)	95.4 (4.9)	91.8 (15.3)	84.0 (20.9)	96.7 (4.3)	98.2 (2.1)	2.16 (0.33)
Mediterranean	91.0 (6.0)	96.1 (3.9)	93.4 (6.4)	90.3 (9.3)	89.2 (9.9)	91.0 (7.6)	91.6 (7.4)	5.49 (1.16)
MENA	93.8 (9.5)	95.0 (5.8)	91.1 (10.4)	89.4 (14.3)	86.4 (18.3)	91.3 (9.5)	90.6 (11.5)	3.88 (1.44)
Caribbean	92.4 (7.9)	93.8 (5.2)	88.0 (11.1)	87.8 (16.7)	87.5 (16.7)	87.9 (11.4)	90.3 (8.3)	4.07 (1.63)
Western Europe	38.0 (28.0)	97.3 (2.4)	93.7 (4.9)	79.1 (19.4)	92.4 (7.4)	89.5 (6.7)	89.5 (6.7)	8.41 (0.83)
SSA	85.1 (14.2)	84.8 (14.2)	74.7 (19.5)	78.6 (18.0)	77.5 (19.7)	72.8 (17.4)	95.3 (6.2)	2.99 (1.08)
Latin America	95.7 (4.7)	95.9 (3.5)	91.1 (7.6)	87.8 (13.3)	89.6 (10.7)	94.0 (5.4)	94.4 (4.3)	3.59 (1.42)
Western Offshoots	-	95.6 (2.9)	91.6 (3.3)	79.7 (26.0)	90.3 (4.5)	90.6 (4.5)	90.6 (4.5)	8.58 (0.76)
Southeast Asia	91.5 (9.5)	91.7 (8.6)	87.4 (11.7)	80.9 (20.6)	85.4 (21.2)	86.6 (12.6)	95.2 (1.9)	3.62 (2.15)
East Asia	92.0 (7.5)	96.6 (2.9)	93.1 (6.4)	90.7 (10.0)	79 (27.5)	94.3 (5.0)	94.3 (6.8)	4.38 (1.64)
Oceania	94.3 (6.8)	86.0 (9.8)	77.5 (12.2)	74.6 (15.5)	77.6 (15.8)	74.3 (13.2)	74.6 (17.8)	2.98 (0.75)
South Asia	87.0 (11.6)	86.5 (11.3)	79.1 (16.5)	67.1 (30.8)	77.6 (18.1)	77.2 (16.6)	93.5 (10.5)	2.80 (1.05)
Central America	94.5 (5.2)	95.2 (3.9)	90.6 (6.1)	89.5 (12.0)	89.8 (9.8)	93.2 (5.1)	93.5 (4.8)	3.36 (0.88)
E. Europe (OECD)	97.4 (2.0)	98.4 (1.1)	96.7 (2.6)	95.1 (10.7)	84.3 (26.9)	96.9 (1.9)	96.9 (1.9)	4.78 (0.92)

Note: The table presents the mean vaccination rates across countries and the Corruption Perception Index (CPI), with standard deviations shown in parentheses.

effects. The results show a positive relationship between CPI and the rate of vaccination. All statistically significant coefficients are positive. Furthermore, whenever they are robust to controlling for linear trends, they are approximately one in magnitude. To interpret this result, note that during the study period (1998–2011), CPI was scaled from 0 to 10, with the higher the better. Our results show that one unit of CPI is associated with an approximately one percentage point (pp) increase in vaccination rate. For example, a difference of 5 points in the CPI between Western Europe and Latin America (see the region-specific means in Table 1) is associated with an approximately 5 pp higher vaccination rate in Western Europe than in Latin America.

We also estimate the relationship of vaccination rate with democracy and civil liberties indices. We adopt the 11 indices of democracy collected on the https://www.gapminder.org website from different think tanks, and normalise them, such that all indices have a mean of zero and a standard deviation of one. We estimate separate regressions for each of the indices, controlling for CPI. Table 3 reports the results. These regressions lead to two insights. First, the CPI coefficient is robust (economically and statistically) to inclusion of any democracy index. Second, conditional on CPI, the democracy indices do not have a robust and statistically significant relationship with vaccination. Therefore, our focus on the corruption-vaccination relationship captures a more important issue than democracy-vaccination or civil freedom-vaccination, even though freedom and democracy are negatively correlated with prevalence of corruption. Finally, in column (12) we include in the regression the Human Development Index (HDI). Even in presence of HDI, the coefficient of CPI remains robust and statistically significant.

Table 2: Vaccination rates and corruption: regression results

	(1) Pooled	(2) BCG	(3) DTP1	(4) DTP3	(5) Hepb3	(6) Hib3	(7) MCV1	(8) Pol3	(9) RCV1
				Panel A: country and year fixed effects					
CPI	1.245***	0.532	0.837**	1.549***	0.398	4.738**	1.223**	1.122**	-0.125
	(0.372)	(0.562)	(0.359)	(0.539)	(1.562)	(2.154)	(0.487)	(0.523)	(0.443)
R-squared	0.563	0.854	0.848	0.881	0.686	0.622	0.897	0.876	0.782
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Vaccine FE	Yes	No	No	No	No	No	No	No	No
				Panel B: country-specific linear trends					
CPI	1.002**	1.016	0.729*	1.471**	1.073	1.832	1.186**	0.840	-0.0375
	(0.457)	(0.669)	(0.437)	(0.675)	(1.687)	(1.821)	(0.588)	(0.640)	(0.553)
R-squared	0.589	0.924	0.910	0.933	0.818	0.840	0.945	0.927	0.893
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-specific linear trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Vaccine FE	Yes	No	No	No	No	No	No	No	No
Observations	14,430	1,489	1,838	1,838	1,422	1,100	1,838	1,838	1,176

Note: The table presents results of the estimation of Equation (4). $***p<0.01$, $**p<0.05$, $*p<0.1$. Standard errors are clustered by country.

Table 3: Vaccination rates, corruption, and democracy: regression results

	Dependent variable: vaccination rate					
	Economist Intelligence Unit				Freedom House	
	Civil liberties	Democracy	Political culture	Government	Civil liberties	Political rights
	(1)	(2)	(3)	(4)	(5)	(6)
CPI	1.039**	1.090**	0.981**	1.032**	1.266***	1.252***
	(0.469)	(0.480)	(0.448)	(0.462)	(0.377)	(0.375)
Coeff. of the index	2.778	3.761	1.190	0.331	-0.583	-0.183
	(2.510)	(3.169)	(1.025)	(1.847)	(0.984)	(0.901)
R-squared	0.592	0.592	0.592	0.592	0.563	0.563
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Vaccine FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,379	7,379	7,379	7,379	14,396	14,396
	IDEA - Democracy Indices				Polity	Human
	Absence of corruption	Checks on government	Civil society participation	Civil liberties	Democracy Score	Development Index
	(7)	(8)	(9)	(10)	(11)	(12)
CPI	1.207***	1.202***	1.229***	1.228***	1.245***	1.045***
	(0.391)	(0.380)	(0.385)	(0.383)	(0.383)	(0.369)
Coeff. of the index	0.383	-1.598	0.257	-1.278	0.0512	47.203***
	(1.225)	(0.989)	(0.779)	(1.247)	(1.144)	(17.670)
R-squared	0.567	0.567	0.567	0.567	0.557	0.550
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Vaccine FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13,212	13,212	13,212	13,212	13,236	14,228

Note: The table presents coefficients of fixed-effects regressions, where vaccination rate is the dependent variable. Vaccination data is pooled (all vaccines in the same data set, controlling for the vaccine fixed effect).The explanatory variables are the normalized democracy and civil liberty indices from https://www.gapminder.org. $***p<0.01$, $**p<0.05$, $*p<0.1$

Mandatory vaccination and corruption

Data and model

The policy choice on vaccination (recommendation only versus mandatory) depends on different parameters. In general, if a state is more sensitive to personal freedom, the government would be less comfortable with forcing its citizens to vaccinate. In addition, as a government is perceived to be less corrupt, citizens trust its recommendations more. Therefore, it may be less necessary to apply a mandatory vaccination policy. Thus, we conjecture that more liberal and less corrupt countries are less likely to adopt the mandatory vaccination policy.

To test this hypothesis, we merge CPI with the VENICE project data (Haverkate et al., 2012), which report vaccination legislation status in the European Union, Iceland, and Norway in 2010. Unfortunately, there is no time dimension in this dataset. Yet, the reported legislation status distinguishes between vaccination laws for 15 diseases. Thus, there is a vaccine dimension, such that the total sample consists of $29 \times 15 = 435$ observations. We estimate Probit regressions, where we consider a dummy for mandatory vaccination (at least for the high-risk group) as the dependent variable, and CPI and the democracy indices (see above details of data used for regressions in Table 3) as explanatory variables.

Results

Table 4 shows the coefficients of the Probit estimation (with standard errors clustered on country level). We observe a significant negative relationship with the probability of adopting mandatory vaccination as the democracy indices and CPI increase. The strongest coefficients are for the civil liberties indices (columns 1 and 5).

Table 4: Mandatory vaccination policy, democracy, and corruption

	Dependent variable: mandatory vaccination					
		Economist Intelligence Unit			Freedom House	
	Civil liberties	Democracy	Political culture	Government	Civil liberties	Political rights
	(1)	(2)	(3)	(4)	(5)	(6)
Coeff.	-3.116***	-2.352***	-0.681***	-1.574***	-2.548***	-1.794***
	(0.639)	(0.468)	(0.130)	(0.339)	(0.572)	(0.581)
Obs.	435	435	435	435	435	435
		IDEA - Democracy Indices			Polity	
	Absence of corruption	Checks on government	Civil society participation	Civil liberties	Democracy Score	CPI
	(7)	(8)	(9)	(10)	(11)	(12)
Coeff.	-1.141***	-1.656***	-0.951***	-1.850***	-3.497**	-0.948***
	(0.203)	(0.276)	(0.248)	(0.546)	(1.450)	(0.166)
Obs.	390	390	390	390	390	435

Note: The table presents coefficients of Probit regressions, where the mandatory status of a vaccine is the dependent variable. The mandatory status is for 15 vaccines in 29 countries in 2010 and taken from Haverkate et al. (2012). The explanatory variables are the normalized democracy and civil liberty indices from https://www.gapminder.org. $***p<0.01$, $**p<0.05$, $*p<0.1$

4 Evidence from Google Trends

In Section 3, we showed that the vaccination rate is negatively correlated with the perception of corruption. However, can we also observe the relationship between concerns about corruption and beliefs about vaccination from the public interest perspective? We employ data from Google Trends. We use the monthly data on searches by country for the following expressions: "vaccination", "vaccination + autism", "MMR + autism", "autism", and "corruption". In addition, we collect data on two placebo search terms frequently searched on the internet: "news" and "weather". The Google Trends data are normalized and take values from 0 to 100. It starts in January 2004, and we have data for 196 months until April 2020 for 180 countries.

Figure 3 shows the average cross-country Google Trends. The distinction between the vaccination, corruption, and autism search terms, and the placebo search terms (weather and news) is very clear. This distinction is even clearer when one plots the logged values (Figure 4).

Furthermore, Table 5 presents the correlation coefficients between the variables (panel A) and their logged values (panel B). The correlation between searches for vaccination, corruption, and autism is 0.4–0.5 in the raw data and 0.6–0.75 in the logged data. However, the correlation of vaccination, corruption, and autism with placebo variables, i.e., news and weather, is only 0.1–0.3 in the raw and 0.2–0.3 in the logged data.

Econometrically, we assess the collected data using factor analysis models. This model tests for the existence of a common latent variable that affects the searches for different items. The results of the factor analysis are shown in Table 6. The first factor clearly groups the vaccination, corruption, and autism search terms with factor loadings between

Table 5: Correlation between items in the Google Trends

	Vaccination	Corruption	Vacc.+Autism	MMR+Autism	Autism	News	Weather
			Panel A: raw variables				
Vaccination	1						
Corruption	0.361	1					
Vaccination + Autism	0.464	0.392	1				
MMR+ Autism	0.381	0.419	0.540	1			
Autism	0.421	0.464	0.551	0.603	1		
News	0.102	0.010	0.138	0.168	0.142	1	
Weather	0.164	0.239	0.246	0.301	0.260	0.188	1
			Panel B: logged variables				
Vaccination	1						
Corruption	0.678	1					
Vaccination + Autism	0.748	0.700	1				
MMR+ Autism	0.734	0.620	0.738	1			
Autism	0.618	0.593	0.703	0.669	1		
News	0.246	0.292	0.298	0.312	0.333	1	
Weather	0.194	0.176	0.199	0.192	0.179	0.09	1

Note: The table presents correlation coefficients between the variables in Google Trends data.

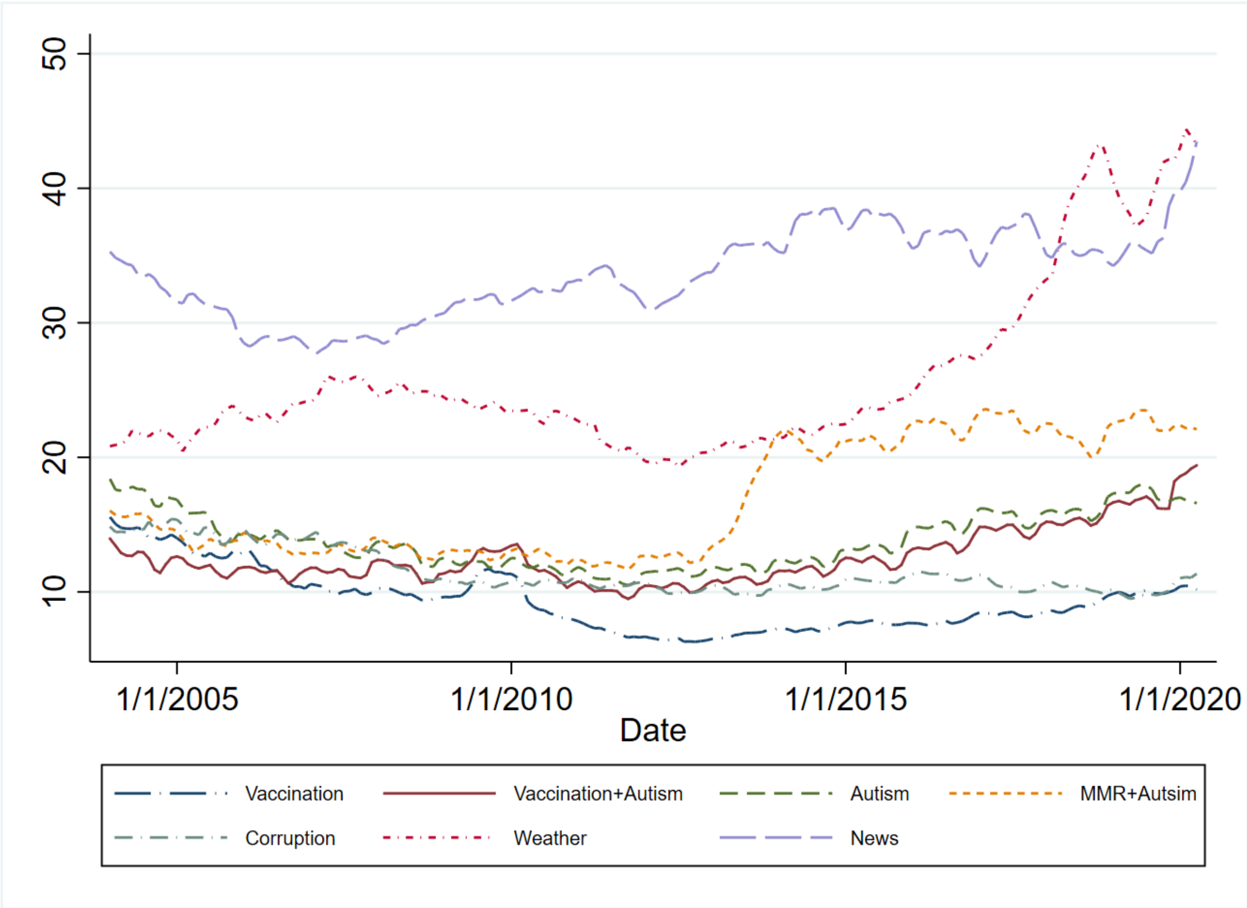
0.56 and 0.75. The corresponding factor loadings with logged data are between 0.77 and 0.88. By contrast, "news" and "weather" have, respectively, factor loadings of only 0.22 and 0.37 in factor analysis with raw data, and 0.23 and 0.36 in factor analysis with logged data. Therefore, we can clearly testify to the presence of a common latent factor that drives public interest in vaccination, corruption, and hypothetical vaccination side effects.

Table 6: Google Trends: factor analysis results

Raw variables			Logged variables		
Variable	Factor 1	Factor 2	Variable	Factor 1	Factor 2
Vaccination	0.56	-0.13	ln (Vaccination)	0.84	-0.14
Corruption	0.58	-0.03	ln (Corruption)	0.77	-0.03
Vaccination + Autism	0.71	-0.07	ln (Vaccination + Autism)	0.84	-0.00
MMR + Autism	0.73	0.04	ln (MMR + Autism)	0.78	0.12
Autism	0.75	-0.04	ln (Autism)	0.88	-0.03
News	0.22	0.23	ln (News)	0.23	0.01
Weather	0.37	0.23	ln (Weather)	0.36	0.20
Num. of Observations	24,831			12,900	

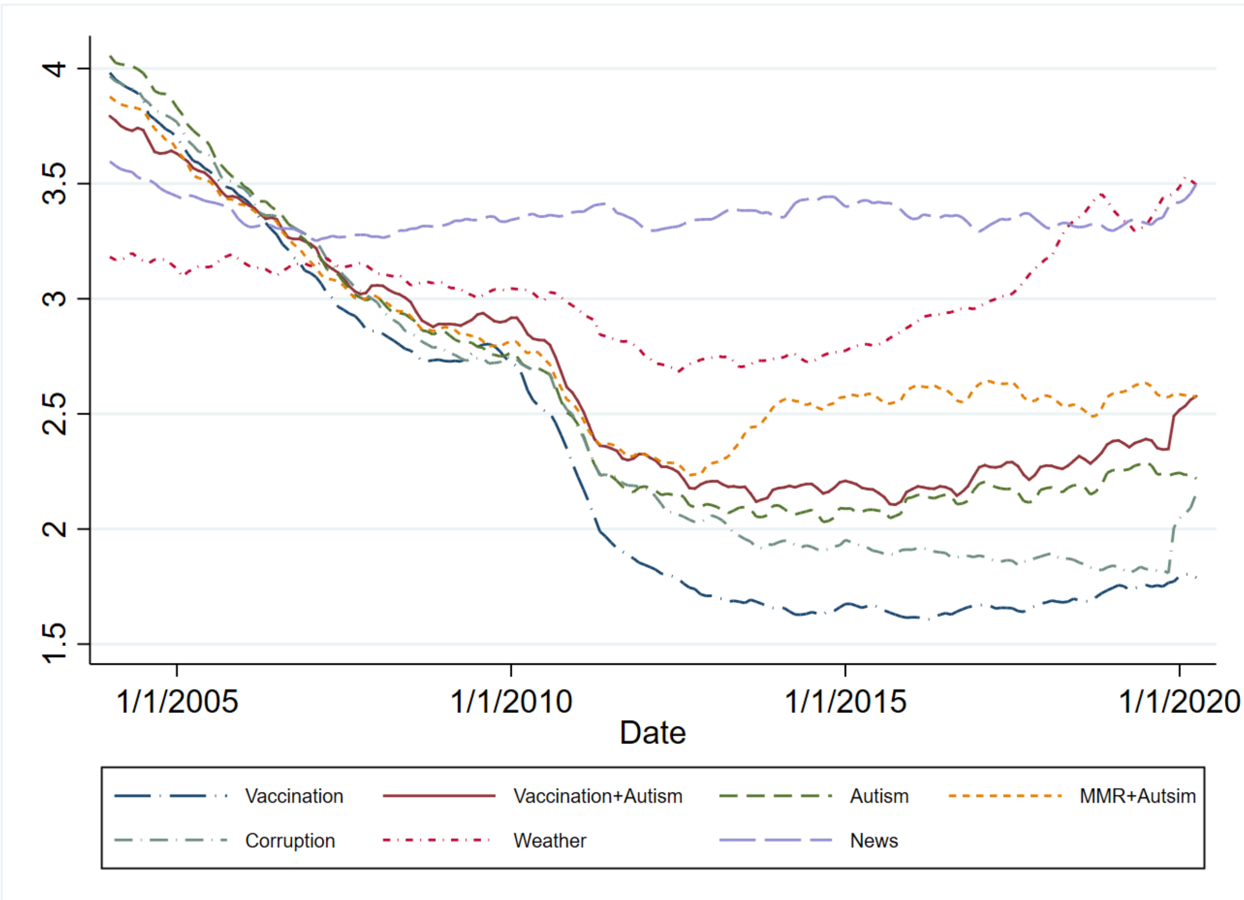
Note: The table presents the results of the factor analysis for the Google Trends data.

Figure 3: Cross-country average Google Trends



Note: The figure shows the average cross-country monthly Google Trends across 180 countries and territories.

Figure 4: Cross-country average logged Google Trends



Note: The figure shows the average logged cross-country monthly Google Trends across 180 countries and territories.

5 Conclusion

We establish, both theoretically and empirically, that the level of corruption, vaccination policy, and vaccination rate are related. If the government is less corrupt, it is more likely to rely on recommendations rather than adopt a compulsory vaccination policy. However, a less corrupt country will observe higher vaccination rates. Moreover, we find evidence that a common factor does exist and drives the public interest in corruption and vaccination.

Some parameters are outside the scope of our analysis. For example, when a government has higher administrative capability, it is easier to enforce the compulsory vaccination policy. In a poor country, the desire to save costs is higher. Therefore, vaccination is less reliable and we expect that fewer people will vaccinate. We leave this and other related questions for further research.

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Appendix

[Proof of proposition 2.1] Consider first a case where a low quality vaccine is harmful, and for citizens it is worse than not to be vaccinated, $l(x) < n(x)$ for all x. In this case, no citizen vaccinates if he believes, with certainty, that G chooses a low-quality vaccination. If a citizen i believes that G chooses the standard quality, he vaccinates if

$$h(x) - c_i \geq n(x). \tag{5}$$

Let c^* be the maximal $c^* \in [0,1]$ such that $x^* = F(c^*)$ satisfies (5). From $h(x) > n(x)$ for $x \in [0,1]$, $c^* > 0$. By strict monotonicity of $F(c)$, $c^* < 1$ implies $x^* < 1$. $x^* < 1$ means equality in (5). If equality holds in (5) for x^*, then, as $h(x) - n(x)$ is decreasing, (5) does not hold for $x > x^*$.

G prefers q to $\bar{q}$ if,

$$b(x) + vx - dx > b(x) - gx - \gamma x^{\alpha}. \tag{6}$$

Let $x^{'} = \min[(\frac{d-g-v}{\gamma})^{\frac{1}{\alpha-1}}, 1]$. Note that $x^{'} > 0$ by $v < d - g$. Inequality (6) holds for $x \leq x^{'}$. $x^{'} = (\frac{d-g-v}{\gamma})^{\frac{1}{\alpha-1}} < 1$ if $(\frac{d-g-v}{\gamma}) > 1$. In this case, $(\frac{d-g-v}{\gamma})^{\frac{1}{\alpha-1}}$ decreases in α and increases in γ.

The result follows $\tilde{x} = \min[x^{'}, x^*]$.

Next, consider a case where $l(x) \geq n(x)$ for some x. If citizen believes that the vaccine is of low quality, he vaccinates if

$$l(x) - c_i \geq n(x). \tag{7}$$

Let c^* be the maximal $c^l \in [0,1]$ such that $x^l = F(c^l)$ satisfies (7). Note that in the case

$l(x) < n(x)$ for all x, $x^l = 0$.

If $x^l \leq x^{'}$, citizens do not vaccinate if they believe that the quality is low, and this case is equivalent to the previous one ($l(x) < n(x)$ for all x). But if $x^l > x^{'}$, then even if quality is low some citizens still vaccinate. Then $\tilde{x} = x^l$, which does not depend on α and γ.

[Proof of proposition 2.2] The selfish G prefers low-quality vaccination for $x > (\frac{d-g}{\gamma})^{\frac{1}{\alpha-1}}$. According to lemma 1, the benevolent G prefers standard-quality vaccination for $x \leq (\frac{d-g-v}{\gamma})^{\frac{1}{\alpha-1}}$. For $\alpha < 1$, as $(\frac{d-g}{\gamma})^{\frac{1}{\alpha-1}} < (\frac{d-g-v}{\gamma})^{\frac{1}{\alpha-1}}$, the selfish G prefers low-quality vaccination for $x = (\frac{d-g-v}{\gamma})^{\frac{1}{\alpha-1}}$.

A citizen i prefers vaccination for $(\frac{d-g}{\gamma})^{\frac{1}{\alpha-1}} \leq x \leq (\frac{d-g-v}{\gamma})^{\frac{1}{\alpha-1}}$ if

$$(1-\rho)l + \rho h(x) - c_i > n(x), \tag{8}$$

and prefers not to vaccinate for $x > (\frac{d-g-v}{\gamma})^{\frac{1}{\alpha-1}}$.

Note that for $\rho = 1$ Equation 8 is equivalent to Equation 5. Recall that $l < 0$. By Equation (8), for sufficiently low l, no citizen vaccinates. Let c^{**} be the maximal $c^{**} \in [0,1]$ such that $x^{**} = F(c^{**})$ satisfies (8). If x^{**} is positive and lower than $(\frac{d-g-v}{\gamma})^{\frac{1}{\alpha-1}}$, for $\rho < 1$ and for $|l|$>0, it is lower than x^*.